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The Propagation of Flowers by Cuttings and Seeds

W. W. Wiggin

OHIO
AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

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THE PROPAGATION OF FLOWERS BY CUTTINGS AND SEEDS

W. W. WIGGIN

INTRODUCTION

The propagation of flowers is one of the most important phases in their culture. Unfortunately, difficulties are often encountered in rooting cuttings and in germinating certain kinds of seeds.

The responses obtained, favorable or unfavorable, are influenced by a number of factors, such as the media in which seeds or cuttings are placed, the treatment of the media, the degree of trimming when preparing the cutting, and the location of the cut. A number of experiments at Wooster have been devoted to these and to other problems of propagation. Results of work carried on during the past 3 years are presented in this bulletin.

METHODS OF PROPAGATION

Most flower crops are propagated by cuttings or seeds. Some crops are propagated by either method satisfactorily. The named varieties are often grown by cuttings only, as they will not come true to variety if grown from seeds. New varieties of the crops that are commonly propagated by cuttings to maintain them true to name originated from seeds, sports, or selections.

Seeds are the most satisfactory means of propagation whenever feasible for the following reasons: Less disease is liable to be transmitted to the crops from the use of seeds; in general, seeds are not as difficult to handle as cuttings; a larger number of plants can be produced on a given area by this method, which is of importance in greenhouse work and in starting outdoor flowers inside in the early spring.

Flower seeds, in general, can be started at almost any season of the year; whereas, it is often rather difficult to start cuttings during certain seasons. The vitality of the crop seems to be maintained to better advantage by seed propagation.

On the other hand, cuttings are more satisfactory in some respects. A larger plant can generally be produced in a shorter period of time. If cuttings are properly selected, more uniformity, as to color, size, and general growth characteristics, is sometimes secured in the resulting crops.

PROPAGATION BY CUTTINGS

There are many kinds of cuttings used for propagation. Some plants, such as shrubs, are propagated by hard- or soft-wood cuttings and by heel, or mallet, cuttings, depending on the season, plant, and other considerations. Greenhouse flower crops are mostly propagated by soft-wood cuttings when the cutting method of propagation is the most satisfactory one to use. This type of cutting only will be considered here.

TEXTURE OF CUTTINGS

A soft-wood cutting or green-wood cutting is taken from the growing parts of the parent plant. The texture of the cutting is important. Different types of plants vary as to the proper texture required, and experience teaches the propagator to recognize this texture.

The literature indicates that a high carbohydrate-low nitrogen ratio is desirable in cutting material. Reid (13) found this to be particularly true for root stimulation.

Experiments were undertaken at the Ohio Agricultural Experiment Station, Wooster, with flowers to determine the relationship between texture of cutting material and rooting. Plants were shaded, both in the field and in the greenhouse, for 3 weeks prior to taking the cuttings. One application of nitrate of soda was applied at the rate of 300 pounds per acre and the cutting material thus produced was compared with material that had been grown without shade or nitrates.

TABLE 1.—Relation Between Texture of Cutting and Rooting

Material	Geraniums, 9-20-27		Coleus, 2-17-28		Geraniums, 9-14-28	
	Rooted, shaded	Rooted, not shaded	Rooted, shaded	Rooted, not shaded	Rooted, shaded	Rooted, not shaded
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Sand	56.1	53.4	....	....	82	66
Slag	75.7	83.3	96	100	36	54
Sand and slag	50.9	41.7	98	47	....	....
Peat and slag	31.4	51.6	95	92	76	59
Slag and sphagnum	....	....	100	96	....	....
Sand and sphagnum	....	....	94	89	....	....
Sand (used 2nd time)	....	....	96	96	59	29
Sand and peat	....	....	100	100	78	82
Sand treated with Semesan	....	....	76	61	....	....
Peat	....	....	....	....	90.3	82.4

Geraniums and coleus were used. One hundred cuttings were grown to a plot. There were three replications with the geraniums and four with the coleus. The experiment was first undertaken from greenhouse-grown cuttings in January 1928, and it was repeated with outdoor-grown cuttings in September 1928. At the same time, different media were being tested. The results are given in Table 1.

It is assumed that the shaded cuttings were of a softer texture than the non-shaded cuttings.

The data, Table 1, indicate that the media used have a great deal to do with the texture of the cuttings. Slag, sand and slag, sphagnum and slag, peat and slag, sand, sand and peat, and peat hold an increasing amount of water in the order given. Changes in the water-holding capacity of media are, of course, possible, due to variations encountered from time to time in the samples of media used, the firmness of the media, and the drainage of the cutting bench. It will be noted that with slag, which dries out very rapidly, an increased number of rooted cuttings occurred when the material had not been shaded. The majority of the remaining media gave increases in rooting when they were shaded and fertilized.

As already stated, the low nitrogen-high carbohydrate ratio has been found by other experimenters to be the desirable condition. The plants that were shaded and fertilized with nitrate of soda should have been relatively high in nitrates and low in carbohydrates when compared with unshaded and unfertilized plants. No chemical determinations were made on the material, but the above statement was assumed.

Water is a very important factor in the rooting of cuttings, and those not properly treated as to watering, shading, and ventilation generally root very poorly. It is an extremely difficult task to keep the environment of the cuttings under the ideal conditions but an attempt was made to do so in this experiment. Too high temperatures, too high or too low moisture content of the rooting media, too bright sunlight, and other common errors encountered were eliminated as far as possible. Under these conditions better rooting was secured with the more succulent textured material. The increase of rooting in the slag, which dried out very quickly, probably was due to the harder textured cuttings being more resistant to the adverse conditions encountered more often in the slag than in some of the other media used.

It is necessary with some crops to use judgment and acquire experience in determining the proper texture; for example, soft growth generally roots better than the harder growth with begonias, but the reverse seems true with poinsettas. A medium texture that is neither too hard nor too succulent is to be preferred with the majority of crops tested. Practical experience will soon teach an alert propagator the material that will give him the best results under his particular conditions.

PLACE AND MANNER OF MAKING CUT

The proper manner of making the basal cut has been considered of importance by writers, investigators, and practical growers. Some have recommended cuts straight across the cutting, thereby making the cut area the smallest possible. Slanting cuts have been recommended by others because of better callusing. Cuts both between the nodes and at the node have been advocated, arguments being given in favor of both.

Experiments were conducted on the place and manner of making the cuts to determine the best methods, (Table 2). Geraniums showed an advantage in favor of the cut at an angle through the node, as compared with the cut straight across the node, in 1927. Coleus gave a better percentage of rooting when cut straight across the node, as compared with the angular cut through the node.

One variety of coleus rooted best when cut at the node instead of between the nodes. Another variety gave the same percentage of rooting when cut at the node as when cut between the nodes.

One variety of coleus gave a better percentage of rooting from the second cutting from the tip than from the tip cutting. Another variety gave a better percentage of rooting from use of tip cuttings than from the second cutting from the tip, or the "not terminals".

There was an advantage for the cut at the node with one variety of coleus as compared with the cut between the nodes, in 1928. With another variety similar results were secured but the advantage was very slight. The figures were 94.4 as compared with 94.9; the difference is not statistically significant. The random cuts were not as good as the cuts at some definite location on the plant.

In 1929, geraniums gave a slightly better percentage of rooting from cuts at the node. Coleus gave 100 per cent rooting from cuts made both at the node and between the nodes.

Cuts made at random, as cuttings are generally taken, rooted with a satisfactory percentage in all cases.

The above figures are taken from the average of cuttings placed in several media at different times throughout the season and with two replications of each treatment. Begonias, achyranthes, chrysanthemums, and carnations were also tested.

TABLE 2.—Place and Manner of Making Cut

Plant used	Treatment	1927			1928			1929		
		Put in	Taken out	Rooted	Put in	Taken out	Rooted	Put in	Taken out	Rooted
		Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
Geranium	Straight across node	384	195	50.5	...	...	...	...	...	...
Geranium	Angle through node	284	171	60.2	...	...	...	...	...	...
Geranium	Straight across node	...	...	...	...	...	...	386	248	64.2
Geranium	Between nodes	...	...	...	...	...	...	371	229	61.7
Coleus (var.) (av. 4 med.)	Between nodes	600	426	71.0	...	...	...	...	...	...
Coleus (var.) (av. 4 med.)	Straight across node	284	209	73.1	...	...	...	...	...	...
Coleus (var.) (av. 4 med.)	Angle through node	148	65	43.2	...	...	...	...	...	...
Coleus (var.) (av. 4 med.)	Cut at random	...	...	...	297	167	80.6	...	...	...
Coleus (var.) (av. 7 med.)	Between nodes	350	167	47.7	126	114	90.4	600	600	100.0
Coleus (var.) (av. 7 med.)	Straight across node	420	243	57.8	126	117	92.8	600	600	100.0
Coleus (var.) (av. 7 med.)	Not terminal	70	66	94.3	...	...	...	...	...	...
Coleus (var.) (av. 7 med.)	Cut at random	...	...	...	540	497	92.0	2986	2971	99.5
Coleus (var.) (av. 9 med.)	Between nodes	350	347	99.1	270	255	94.4	...	...	...
Coleus (var.) (av. 9 med.)	Straight across node	350	347	99.1	216	205	94.9	...	...	...
Coleus (var.) (av. 9 med.)	Not terminal	98	92	93.8	...	...	...	...	...	...
Coleus (var.) (av. 9 med.)	Cut at random	140	105	75.0	306	280	91.5	1640	1492	91.0

The figures for 1927 are low in some instances; since some of the media or treatments used gave very low percentages of rooting the average of all treatments was lowered. In one instance, 43.2 per cent rooting occurred with the coleus which is, of course, very low.

The data in Table 2 indicate only slight increases in the majority of cases. Such small increases would not be sufficiently significant to warrant the inconvenience of making the cut in any particular way, when propagating the crops listed.

LOCATION OF ROOTS

The place of origin of the roots is an important phase of propagation when making cuttings. A cut at a definite location where rooting is most apt to occur is preferable to one at some other location. The formation of roots at the base of the cutting is desirable for ease in potting the cutting.

As already shown, no definite relationship exists in the crops tested between the place of cut and the percentage rooted. An attempt was made to determine whether the roots were formed at the node or between the nodes in some of the different species of plants.

Carnations, chrysanthemums, geraniums, fuchsias, coleus, begonias, and achyranthes rooted mostly at the basal end of the cutting. Occasionally, roots were formed on the begonias and geraniums above the basal-end roots, regardless of whether the cut was made at or between the nodes. Vinca (vine), English Ivy, and Hagenburger's variegated ivy produced the greatest amount of roots below the buds on the nodes. The majority of the roots were formed within one-half inch of the node and were in a line paralleling the stem.

The nodes on some plants are more protruding than on others. It would seem that roots on plants with distinct nodes, such as the vines mentioned, form just below the nodes. Although the cuttings will root in this area regardless of where the cut is made, there is an advantage in making the cut from one-half to one inch below the node. Roots will then be formed largely on the lower regions of the cutting, and, as previously stated, the rooted cuttings can be potted more easily than where the roots are produced higher on the cutting.

Many plants, such as chrysanthemums and coleus, rooted at the end of the cutting. These plants are more succulent and are not as long between the nodes as the vines nor are the nodes as conspicuous. Cuts could be made promiscuously on these succulent plants and the roots would still be produced at the basal extremity of the cutting, with the same advantage in case of potting.

LOCATION ON PLANT WHERE CUTTING IS TAKEN

Certain plants have been mentioned in floricultural writings as growing differently when propagated from different parts of the mother plant. White (14) states that carnation cuttings taken from near the base of the plant are "grassy", cuttings high on the flowering stems produce weak spindling plants, whereas those taken half way up the stem are preferred.

Cuttings were taken from different parts of carnation plants and their yields kept during the flowering season. There were 72 plants per row in Bed 5, with nine plants to a plot, in eight plot treatments. There were 81 plants per row in Bed 6 with nine treatments. Mrs. C. W. Ward was the variety used.

TABLE 3.—Yield of Cuttings from Different Locations on Plant

	Location on plant	Date taken	Av. flowers per plant	Av. stem length
			Number	*Inches*
Bed 5, Row 1..........	Tip cuttings	2/ 1/29	10.85	19.62
Bed 5, Row 2..........	Side shoots	2/ 1/29	9.29	19.85
Bed 5, Row 7..........	Base shoots	1/17/29	10.30	20.30
Bed 5, Row 9..........	Side shoots	1/17/29	10.61	20.67
Bed 5, Row 5..........	High on flowering stem	12/14/28	11.30	20.15
Bed 5, Row 6..........	Side shoots	12/14/28	10.51	20.75
Bed 6, Row 3..........	Base shoots	1/17/29	10.25	21.50
Bed 6, Row 7..........	High on flowering shoot	1/17/29	10.50	20.95
Bed 6, Row 4..........	High on flowering shoot	1/ 3/29	10.14	21.20
Bed 6, Row 5..........	Side shoots	1/ 3/29	11.97	21.08
Bed 6, Row 8..........	Tip cuttings	2/ 1/29	10.59	21.30
Bed 6, Row 9..........	Side shoots	2/ 1/29	10.39	21.25

Table 3 shows that there was no consistent advantage due to selecting cuttings from any one particular location on the mother plants.

There has been some controversy concerning the selection of the propagating material from high-yielding plants. In fruit work this is known as "pedigreed" nursery stock, and the selection of buds from high-yielding trees has been found to be of questionable value. A test was conducted with greenhouse plants to determine the value of selecting the cuttings from high-yielding plants.

The poorest and best plants of pompons and chrysanthemums were selected from the varieties in the fall of 1927. Cuttings were taken from these and the growth and yield recorded for each lot.

There was no significant difference between the two lots of stock plants, both lots being equally healthy, which is very important, as only healthy stock plants should be used for propagation purposes.

Genetically, the variety or group of plants resulting from plants produced asexually (without pollination), as by cuttings, is termed a "clone". All the individuals in a clonal variety are indirectly parts of the original plant of that variety. Theoretically, there should be no difference in their yield, if all the individuals were treated identically. The variability encountered in clonal varieties is neither due to selecting cuttings from high- or low-yielding parent plants nor to the location of the cut on the parent plant, but rather to cultural conditions and to the response of the individual plant to these treatments.

Some crops, such as Lorraine Begonias, will only root satisfactorily from tip cuttings; whereas others require leaves or other parts of the plant in order to increase the planting stock sufficiently.

TRIMMING THE CUTTINGS

When a portion of a plant is removed for a cutting the water supply from the roots of the plant, at least, is cut off. Transpiration, or the loss of the water by the leaves, must be reduced or the cutting will wilt.

Propagators for many years reduced the leaf area of the cuttings to prevent wilting. Trimmed cuttings, with some types of plants in particular, take up less space in the cutting bench, which is also an advantage. The promiscuous trimming of cuttings is still a common practice.

Zimmerman and Hitchcock (17) found that with cuttings of evergreen holly it was desirable to leave as many leaves on the cuttings as could be kept in good condition. Experiments were started at Wooster in the spring of 1928 to determine whether this same principle would hold true in the case of greenhouse plants.

The results secured when Mrs. C. W. Ward carnation cuttings were trimmed are given in Table 4. There were 1250 cuttings used in each treatment, divided among eight plots of sand. The cuttings labeled "no trimming" were placed in the media just as they were removed from the parent plant. Those designated by "medium trimming" were prepared by removing a portion of the tips of the leaves by cutting them when they were bunched ready for the cutting bench. The tips of the leaves on the base, sides, and growing end were removed for the "heavy-trimmed" plots. The cuttings were placed in the bench February 15 and removed March 12. The average of the eight plots is given in Table 4.

TABLE 4.—Trimming Carnation Cuttings

Degree of trimming	Rooted	Damped-off
	Per cent	*Per cent*
None	94.8	2.3
Medium	93.4	3.1
Heavy	92.2	2.8

The non-trimmed cuttings rooted best, and the more leaf area removed the less the rooting secured, Table 4. The advantage for any treatment was not great, however. The real advantage for the light or non-trimmed cuttings was in the time saved from the trimming operation.

A similar test was run in the fall of 1928 on Red Wing geraniums and Firebrand coleus. The cuttings were placed in six different media to determine any possible existing relationship between the moisture of the media and the degree of trimming needed by the cuttings. One hundred cuttings of each variety were placed in each treatment with eight replications. The geranium cuttings were taken on September 14 and removed on October 29. The coleus were taken on September 19 and removed October 9.

TABLE 5.—Trimming Coleus and Geranium Cuttings

Degree of trimming	Number rooted						Average all media
	Sand	Peat	Slag	Sand (used)	½ Peat ½ Sand	½ Peat ½ Slag	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Geraniums							
None	68.5	74.3	71.4	74.3	100	82.9	**78.6**
Medium	65.9	90.3	53.7	58.6	75.6	75.6	**69.9**
Heavy	65.1	93.1	48.6	58.2	51.2	69.8	**64.3**
Coleus							
None	100	100	100	100	100	100	**100**
Medium	100	100	100	100	100	100	**100**
Heavy	100	100	100	100	100	100	**100**

The geraniums show results somewhat similar to those recorded for carnations in Table 4; only the differences between heavy trimming and no trimming were more significant, there being a difference of 14.3 per cent for an average of all media in favor of the non-trimmed cuttings. Non-trimmed geranium cuttings require considerably more space in the cutting bench.

Coleus rooted 100 per cent for an average of all treatments, regardless of the degree of trimming.

The geraniums show differences when trimmed differently and the cuttings placed in different media. The closeness of the percentages of rooting in the case of the sand and the wide variation in the case of the peat and slag are interesting. Peat as a medium holds considerably more water than slag. It might be expected that the cuttings in the media that were relatively dry would show larger increases if heavily trimmed than in media that held more moisture. The opposite proved to be the case. A possible explanation is that the untrimmed cuttings and the moist media made a better environment for the spread of the damping-off fungus. The untrimmed cuttings apparently produced more shade on the slag, which caused a diminished evaporation and a resulting increase in the percentage of rooting following the removal of the least amount of foliage.

Similar results in favor of light, or no, trimming have since been secured on chrysanthemums, begonias, and other lots of carnation, geranium, and coleus cuttings.

The difference in percentage of rooting only is given in the tables. An increase in root and top development in practically every instance was obtained from the untrimmed cuttings. This increased development was much more noticeable than the increases in percentage of rooting, Figure 1.

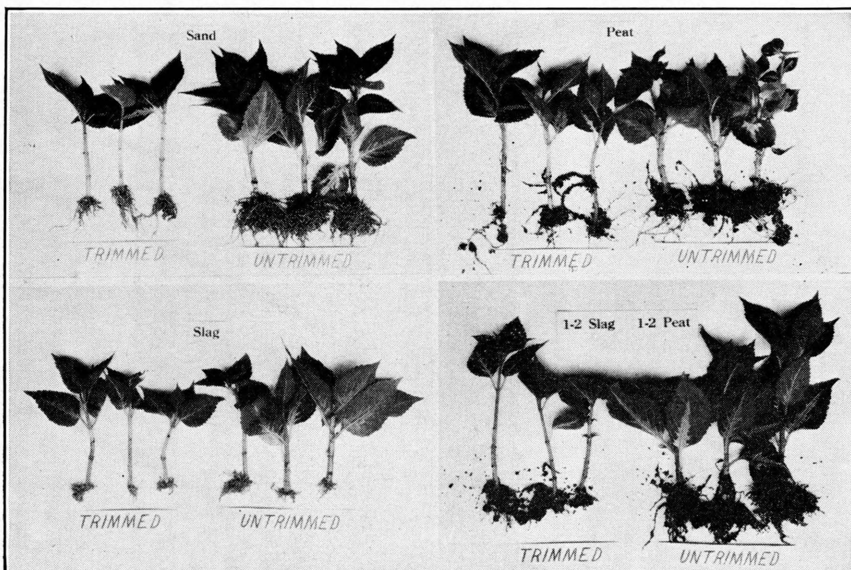

Fig. 1.—Effect of trimming and media on the rooting of coleus cuttings

It is evident from the foregoing tables and discussion that the promiscuous trimming of cuttings before placing in the cutting media is not a wise practice with the crops tested. Greater root and top development and an increase in percentage of rooting were secured with the untrimmed and lightly trimmed cuttings.

The removal of foliage, the loss of roots, or any operation that disturbs the normal "balance" of the plant seems to check its development. Trimming off the foliage of cuttings apparently acts in a like manner.

The loss of this "balance" in the plant, the loss of stored foods and chlorophyll, and the effect of shading the media by the cuttings themselves apparently are of more importance than the reduction of transpiration by reducing leaf area, particularly if the cutting bench is kept properly moistened and shaded so that wilting does not occur.

To summarize, the number of cuttings that it is possible to place in a given area, the effect of moisture and damping-off, the medium to be used, and the plant material itself are involved in the consideration of trimming the cuttings.

ESSENTIALS OF A GOOD CUTTING BENCH

A good cutting bench properly located is essential for success in rooting cuttings. Conditions which retard top growth and, at the same time, promote active root development are desired. The cutting bench should be so located that a good control of the environment of the cuttings is possible at all times.

Since temperature is very important in rooting cuttings, there should be sufficient radiation near the cutting bench so that the proper temperature can be maintained. Both the temperature of the air surrounding the tops of the cuttings and the temperature of the media in which the cuttings are placed must be considered.

TABLE 6.—Effect of Temperature of Air on Rooting Cuttings

Media	50° air temperature		60° air temperature	
	Av. rooted	Av. damped-off	Av. rooted	Av. damped-off
	Pct.	*Pct.*	*Pct.*	*Pct.*
Sand	90.9	9.1	65.0	23.1
Slag	80.2	19.8	59.6	18.4
Sand and slag	81.6	12.4	56.1	36.5
Peat and slag	79.5	17.3	45.5	50.9
Average	83.0	14.6	56.5	32.2

Cutting benches were placed in two different locations for experimental purposes. One bench was in a house having a higher average air temperature than the other. Bottom heat was obtained by placing the benches over some of the heating pipes and enclosing the space below the bench with paper at various heights to hold the heat. The other environmental factors were kept as nearly the same as possible for both benches. Four different media were used in these benches. Geraniums, coleus, fuchsias, carnations, chrysanthemums, begonias, and achyranthes were rooted in the benches.

The average percentage of rooting and damping-off of all the different genera of plants tested, for the four lots tested and the three replications, is given in Table 6. The totals of damped-off and rooted cuttings do not equal 100 in every case. The difference between these two figures indicates the cuttings that did not root, but still did not damp-off. These cuttings were replaced in the media and some rooted. The number that rooted, however, was not figured in the averages. Commercially, it will not generally be found profitable to replace cuttings that have not rooted when the majority are ready to be taken from the cutting bench.

The cooler air temperature was preferable for the plants tested, Table 6. An air temperature of 50° F. was best in the case of the four media tested.

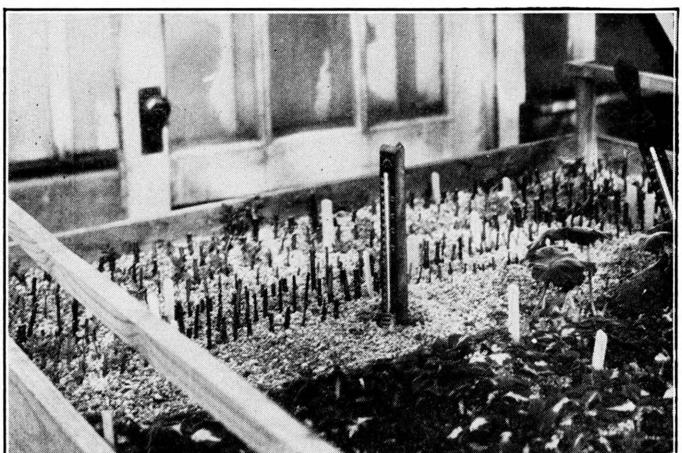

Fig. 2.—Recording top and bottom temperatures of the medium in the propagation experiments on hard- and soft-wood cuttings

The humidity of the air is dependent on the moisture and the temperature. No definite figures were obtainable on humidity with the equipment available. Observation leads to the conclusion that a certain degree of humidity reduces transpiration and indirectly reduces wilting. Too high temperatures, accompanied by high humidity, are conducive to a relatively high percentage of damping-off. This will be discussed in more detail under the heading of "Watering".

An increase in the temperature of the media at the bottom of the bench has been recommended by many writers without data to substantiate their claims. An increase of 10 degrees has often been recommended. An attempt was made to obtain some data on "bottom" temperatures. A soil thermometer was placed one-half inch below the top surface of the soil and another was placed one-half inch above the bottom of the soil, Figure 2. The bench was placed in a house that was maintained at 60° Fahrenheit.

The thermometers were read at the same hour daily. An attempt was made to have the bottom temperature 10 degrees higher than the top temperature, but this was possible only to a limited extent, as indicated in Table 7.

TABLE 7.—Temperature of Media

Date	Sand		Slag		Sand and slag		Slag and peat	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
January 19	62	68	62	73	62	70	62	73
January 20	70	72	64	76	60	72	60	72
January 23	59	71	60	80	60	73	58	80
January 24	56	70	57	74	58	72	58	76
January 25	62	70	60	76	62	72	61	74
January 26	62	78	62	84	62	80	60	84
January 28	62	69	61	78	60	70	59	74
January 29	62	67	60	73	63	71	....	75
January 31	60	70	62	80	62	72	60	76
February 1	60	72	60	82	60	76	60	78
February 2	60	71	62	78	60	73	60	78
February 4	62	76	60	82	60	78	60	78
February 8	60	74	60	80	59	77	60	79
Average	61.3	71.4	60.8	78.2	60.6	73.5	59.8	76.7

The top and the bottom temperatures for the four media were recorded with their averages for a 13-day period, Table 7. The top temperature, which is governed to a great degree by the temperature of the greenhouse, ran quite constant in most cases. Bottom temperatures varied a great deal, the amount depending on the media used. The more porous the media, apparently, the less water it holds and the greater the difference between the top and bottom temperatures. The figures indicate the variations obtained in attempting to regulate bottom temperature.

Tests were conducted in benches with the radiation pipes for bottom heat and in cans of sand immersed in thermostatically controlled water tanks. These tests are not sufficiently conclusive to report at this time. It is evident, however, that damping-off, as well as the growth of the cutting, is affected differently by the temperature of the medium.

Rooting processes are apparently processes of growth. The temperature that is most satisfactory for the growth of the plant apparently is satisfactory for the rooting process. Carnations are grown at temperatures near 50° Fahrenheit, and they rooted satisfactorily at this temperature. A proper manipulation of shade and of water should keep the cuttings from wilting when subjected to these temperatures.

In addition to the proper air temperature and the proper temperature of the media, a good cutting bench should be so situated that the cuttings can be shaded properly so that a proper humidity can be maintained with the least possible trouble. In general, a low, separate house with continuous ventilation on both sides of the ridge is a good place for the cutting bench. The heating pipes can be advantageously placed beneath the bench, or at least part of them.

The bench should not be too wide for the easy manipulation of the cuttings. Good drainage in a cutting bench is also essential. A bench of ordinary construction having these requisites serves the purpose satisfactorily.

MEDIA FOR CUTTINGS

The medium in which cuttings are to be rooted necessitates attention in propagation experiments. A rooting medium should hold sufficient moisture for the cutting; it should be sterile, or at least not contain a large quantity of fungi or bacteria that will attack the cuttings and cause their decay; it should be relatively cheap and easy to obtain; and it should produce a high percentage of rooting of the cuttings if possible.

Zimmerman and Hitchcock (17), Chadwick (3), and Johnson (10) report the effect of different media on the rooting of cuttings, mostly hardwood ornamental. They report advantages for different media with certain kinds of cuttings. Peat moss is used in many greenhouses and has been tested quite extensively as a propagating medium. Slag, a by-product of the steel industry, has been advertised and sold extensively in Ohio as a desirable propagating medium. Sand has long been considered the desirable medium. Other media are often used by individual propagators.

Tests on the value of the different media have been conducted with herbaceous greenhouse materials at the Ohio Experiment Station for 3 years. Sand, slag, peat moss, sphagnum moss, and different combinations of these have been tested. The use of the medium for more than one lot of cuttings and the disinfection of the medium with Semesan have also been included in the tests.

Many kinds of the common commercial greenhouse cut-flower and pot plants that are propagated by cuttings have been tested in the different media.

Table 8 gives the results secured with geraniums, coleus, and achyranthes when they were placed in the cutting bench in the fall of 1927. There were 1918 cuttings used in this lot, divided into small lots in each medium with three replications for each treatment.

TABLE 8.—Effect of Media on the Rooting of Geraniums, Coleus, and Achyranthes

Cuttings set on September 27, 1927

Media	Rooted	Damped-off
	Pct.	*Pct.*
Sand	90.9	9.1
½ sand—½ peat moss	86.0	14.0
½ sand—½ slag	81.6	12.4
Slag	80.2	19.8
½ slag—½ peat moss	79.5	17.3
½ sand—½ sphagnum moss	77.5	15.2
½ slag—½ sphagnum moss	72.4	21.1

Sand gave the best percentage of rooting, with the other media following in the order given in the table. The difference between the percentage rooted, plus the percentage damped-off, and 100 per cent indicates the number of cuttings that had not rooted, but still were not rotted, when the majority of the cuttings were ready to pot. As stated previously, these cuttings that had not rotted were replaced in the media. The number that rooted then, however, is not included in the figures and is not of commercial importance in the majority of cases. Commercially, as a general rule, these unrooted cuttings should be discarded.

Table 9 gives the results secured with the different media on carnations and chrysanthemums during the winter of 1927-1928. There were 800 carnations and 850 chrysanthemums used in this test. They were divided into three replications for each medium treatment. The Mrs. C. W. Ward was the variety of carnation used, and there were nine varieties of large-flowered and pompon-flowered chrysanthemums used.

TABLE 9.—Effect of Media on the Rooting of Carnations and Chrysanthemums
Cuttings set January 10, 1928

Media	Carnations		Chrysanthemums	
	Rooted	Damped-off	Rooted	Damped-off
	Per cent	*Per cent*	*Per cent*	*Per cent*
Sand (used second time)	98.0	2.0	92.6	7.4
Sand (new)	97.0	3.0	97.4	2.6
½ sand—½ sphagnum moss	97.0	3.0	97.0	3.0
Slag	95.0	5.0	97.6	2.4
½ sand—½ peat moss	93.0	7.0	92.6	7.4
½ slag—½ peat moss	92.0	8.0	94.9	5.1
½ slag—½ sphagnum moss	91.0	9.0	96.1	3.9
½ sand—½ slag	90.0	10.0	95.4	4.6

The sand used the second time gave the largest number of rooted cuttings, new sand was next, and so on in the order given. On the chrysanthemums, slag led with 97.6 per cent rooting, followed by new sand with 97.4. The carnations and chrysanthemums rooted with a good percentage in all of the media; there was only a difference of 8 per cent in the case of the carnations and 5 per cent in the case of the chrysanthemums between the highest and the lowest number rooted. All gave a good commercial percentage of rooting.

A great deal of difference was noted in the different media as to the management they required; slag, for example, dried out very much quicker than some of the other media. The matter of the moisture requirement of the different media, however, is discussed later.

TABLE 10.—Effect of Media on the Rooting of Coleus, Begonias, Fuchsias, and Geraniums
Cuttings set February 17, 1928

Media	Rooted	Damped-off
	Per cent	*Per cent*
⅔ sand—⅓ slag	95.7	4.2
Sand (used second time)	94.7	5.2
Slag	93.6	6.3
⅔ slag—⅓ Sphagnum moss	92.4	7.5
Sand (new)	89.3	9.5
⅔ sand—⅓ peat moss	88.6	11.3
⅔ slag—⅓ Sphagnum moss	88.5	11.3
⅔ sand—⅓ Sphagnum moss	87.9	10.6
Sand treated with Semesan	50.5	34.9

Table 10 gives the results secured with Firebrand, Verschaffelti, and Golden Bedder coleus, Red Wing geranium, Lorraine begonia, Mrs. C. W. Ward carnations, Figure 3, and Pink Beauty fuchsias. There were 2124 cuttings used in the test, divided among the different media, with three replications of each medium.

No great differences in the results from various media occurred except with the sand treated with Semesan. The sand in this case was treated with the recommended solution of Semesan 2 weeks previous to placing the cuttings in it.

Changing the media mixtures from 1/2 to 2/3 as noted made no appreciable difference in the rooting. Here, as has been noted previously, all the media and combinations gave a commercial percentage of rooting except the sand treated with Semesan. Firebrand coleus, Pink Beauty fuchsia, and Red Wing geraniums were tested in the fall of 1928 to test different degrees of trimming. These were placed in some of the different media. Table 11 gives the results of the different media on the rooting of these crops for another season. There were 1854 coleus, 1200 geraniums, and 600 fuchsia cuttings divided among the media treatments and their three replications.

TABLE 11.—Effect of Media on the Rooting of Coleus and Geranium Cuttings
Cuttings put in September 4, 1928

Media	Coleus		Geraniums	
	Rooted	Damped-off	Rooted	Damped-off
	Pct.	*Pct.*	*Pct.*	*Pct.*
Sand (new)	99.7	.3	58.4	38.6
Peat mcss	99.2	.6	80.8	16.9
½ peat moss—½ sand	97.9	1.2	66.2	38.5
Sand (used second time)	97.4	1.2	47.9	47.1
½ peat moss—½ slag	96.4	2.3	64.9	35.8
Slag	93.9	1.1	46.9	33.1

No significant differences are shown in Table 11 in regard to the rooting of the coleus cuttings. The geraniums rooted the best in peat moss or combinations containing it. This was in the fall when the weather was hot, and a great deal of sunshine was available.

The same media were tested in midwinter on Mrs. C. W. Ward carnations, Yellow Turner chrysanthemums, Firebrand and Verschaffelti coleus, and achyranthes. There were 2878 cuttings divided among the six media and their three replications.

The sand gave a better percentage of rooting than the peat moss, Table 12. The slag in this series was from a different lot than that used in 1927 and 1928; that used in the 1929 tests was decidedly poorer than that used the two previous seasons. It will be noted from some of the previous tables that, in general, the medium that holds a relatively large amount of water had a larger number of cuttings root in it during the hotter seasons of the year. Media that hold a relatively small amount of water gave good percentages during the dark, cloudy weather encountered in Ohio in winter. This was true even though a conscientious effort was made to hold the moisture content of the media satisfactory for the cuttings at all times.

TABLE 12.—Effect of Media on Rooting of Carnations, Chrysanthemums, Coleus, and Achyranthes

Cuttings put in January 4, 1929

Media	Rooted	Damped-off
	Pct.	*Pct.*
Sand	98.5	1.5
Peat moss	97.3	2.7
½ sand—½ peat moss	96.8	3.2
½ peat moss—½ slag	95.6	4.4
Sand (used second time)	92.6	7.4
Slag	91.1	7.6

Sand, in most cases, was one of the best media. Several different sands were used, ranging from a sharp, washed sand to one of a fine texture that made the water cloudy when it was watered, indicating the presence of quite a large amount of silt and clay. Sand, as a general rule, is relatively cheap and easy to obtain, and propagators should be successful with it.

Peat alone, or a large per cent of peat with another medium, made the task of inserting the cuttings more troublesome. The addition of peat to a medium is recommended during hot weather or where a propagator is inclined to neglect watering.

Sphagnum moss makes the insertion of the cuttings a little more difficult than sand; it takes time to mix with the sand, and, in general, has no advantage over the sand alone.

Slag is not uniform. Some samples of slag root many plants very well, especially during dark weather; other samples of slag prove very unsatisfactory, Figure 4. Slag has been advertised as having an invigorating effect on the roots of the cuttings. Figure 3 shows the effect of the different media on the size of roots. Those media that tend to cling to the roots appear to have a larger mass of roots than those taken from the sand. This is in part due to the material adhering to the roots, but there is also some difference in the size of roots produced in the different media.

Slag may also contain quite a large amount of small glass particles which make it very undesirable for the worker.

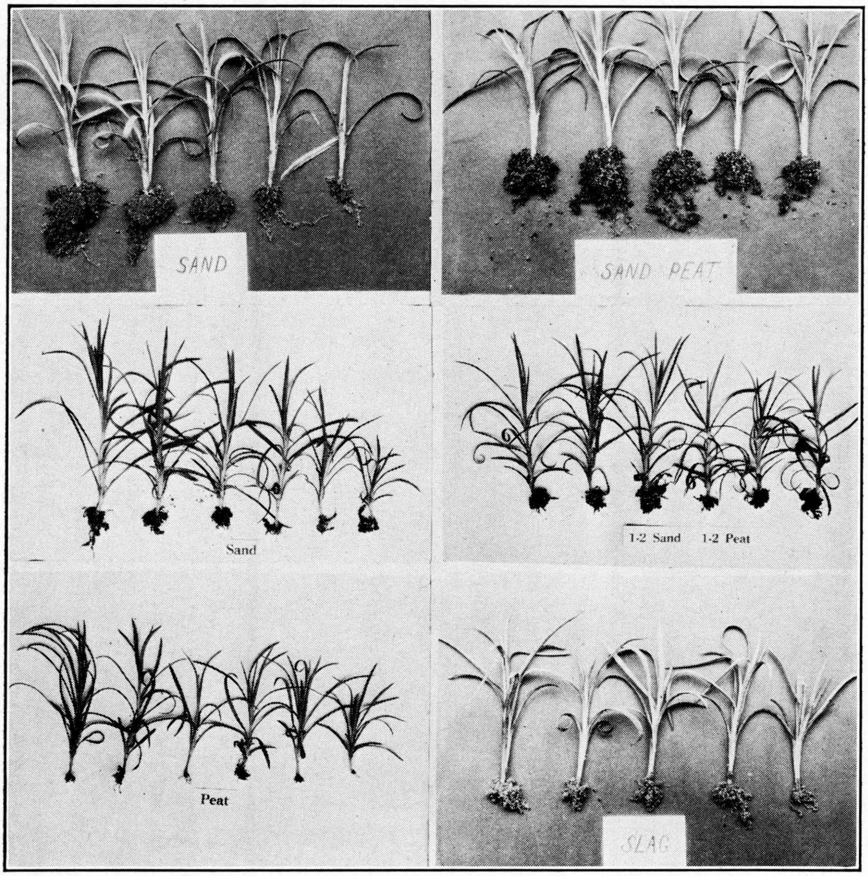

Fig. 3.—Effect of media on carnation cuttings

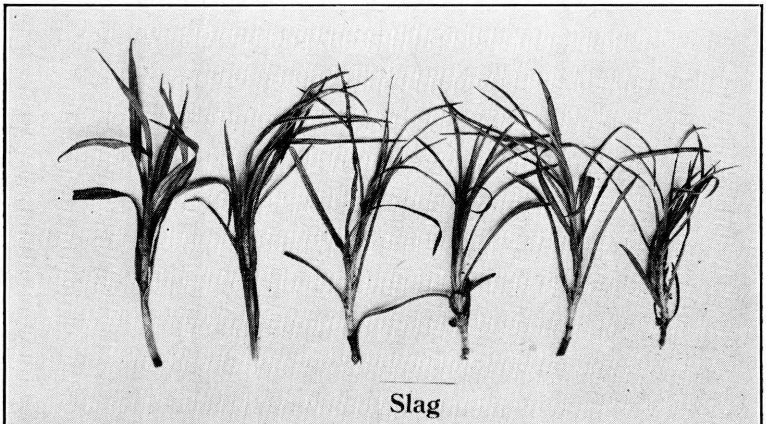

Fig. 4.—Some samples of slag were very detrimental, as shown

Sand used the second time cannot be recommended without some treatment to destroy the fungi in it. Although the propagator has been successful with sand of this kind, trouble is very liable to occur and such occurrences are costly. The treatment of the sand for use a second time is discussed later in this bulletin.

In conclusion, all media tested have given a satisfactory per cent of rooting with the crops tested if they are properly treated, Figure 5. The environment of the cutting in general is fully as important as the medium used.

PLACING THE CUTTING IN THE MEDIUM

Cuttings are generally placed in the medium by running a flat trowel along the edge of a straight edge, placing the cutting in the groove thus made, and firming around them by finger or other means.

The only point in this operation that was doubtful was the proper depth to place the cutting in the medium. Observation has shown that placing the cutting with ½ inch covered by the medium, (i. e., shallow) is not desirable in most instances. Deeper setting, or placing the cutting with about 2 inches in the medium, would be preferred. Of course, a great deal depends on the plant that is to be propagated, the amount of moisture in the medium, the temperature of the top and bottom of the medium, and other common environmental factors.

Cuttings in general, however, will root better if placed with a good portion of the stem covered with the medium.

Carnations are apparently an exception to this statement. They do not tolerate deep setting in the medium or deep potting after they are rooted.

CARE OF THE CUTTING BENCH

The general care given the cutting bench while the cuttings are in it is of the utmost importance. This has already been indicated in a discussion of the different media. It is of enough importance to be given further consideration.

Watering and shading the cutting bench are the most important steps in its general care and by careful attention to them the wilting of cuttings is mostly controlled.

Water is generally applied along the row of cuttings after they are placed in the medium to firm it around the cutting and to eliminate air spaces. Then applications of water should only be made as needed. Damping-off is more apt to occur if the cuttings are kept too wet. Wilting results from too little water, provided there is proper shading. Light sprinklings given the cutting bench at frequent intervals during the day in hot weather seem to be beneficial for some crops.

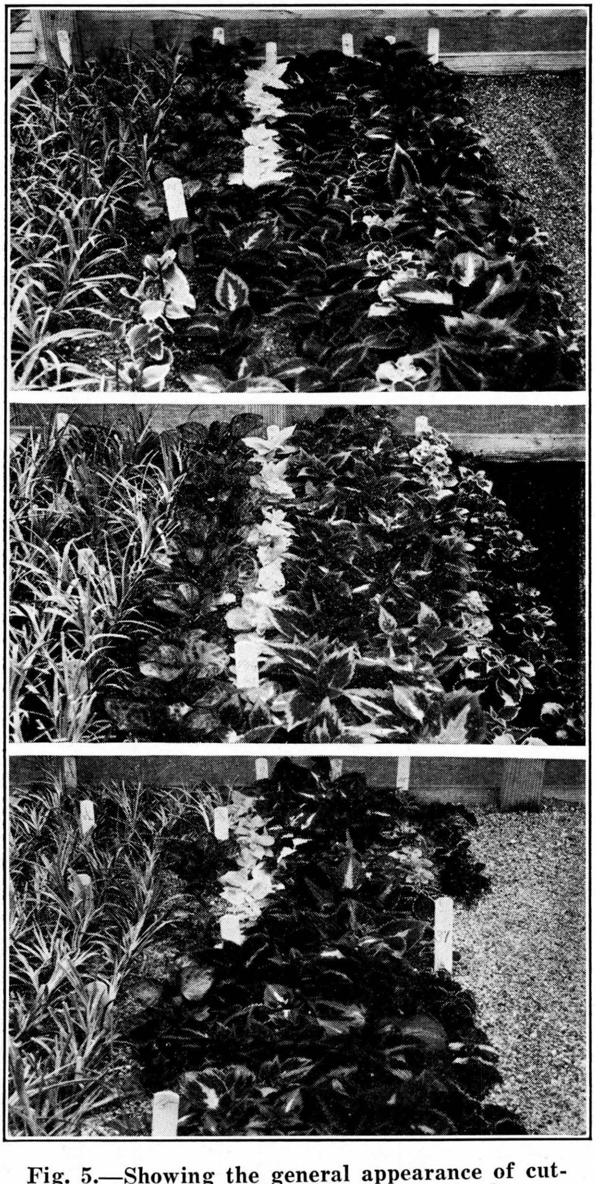

Fig. 5.—Showing the general appearance of cuttings in different media. Top—Sand, Middle—Peat, Bottom—Slag

Shading in propagation, as in the later growth of some crops, must be properly done if best results are to be secured. Shade is usually produced in greenhouses by the use of materials applied to the glass of the propagating house or by newspaper, cheesecloth, or other screening materials placed over the cutting bench. Where a large quantity of some one plant is to be propagated, best results are secured by putting shading materials on the glass. Where small quantities of several kinds of plants are to be rooted, a better control of shade can be accomplished by shading each lot as needed. A partial shade on the glass accompanied by the inside shade in summer makes a good arrangement. A house without shade but with rather poor light or a house with inside shade generally does very well in the winter months. The inside shades have to be regulated very carefully, and, if neglected, give poor results. The shading of plants by newspaper and the like takes considerable time and so is expensive.

Cuttings should be completely shaded when they are first placed in the medium, especially in warm weather. Shade becomes less important as the cuttings become established and in dark weather. Overshading fosters damping-off and a yellow, unhealthy color in the leaves.

A test was conducted during the spring of 1930 on the amount of water applied to the cutting bench. Sand was used as a medium. One set of cuttings was watered as near correctly as possible. Another lot was given more water than was considered advisable. Still another lot was kept drier than was considered good practice. There were 100 cuttings used of each plant, with two replications. The figures given are an average of the three plots.

TABLE 13.—Effect of Moisture on Rooting

Crop	Dry	Considered ideal	Wet
Geranium	40	73	45
Fuchsia	100	100	100
Begonia	92	100	92
Ivy	71	100	100
Average	73	93	84

Cuttings kept neither too wet nor too dry are more liable to root than those kept at either extreme, Table 13. Keeping the medium too dry is particularly detrimental.

Further studies on moisture relations are being conducted with apparatus that gives much more accurate control of the moisture supplied the cuttings, as this phase of propagation seems very important.

TIME REQUIRED FOR ROOTS TO FORM

The time required for roots to be formed on the cuttings must be considered in propagating tests. Evergreen cuttings and some deciduous shrub cuttings take several weeks and even months to form roots. The soft-wood cuttings of common greenhouse plants do not require nearly as much time. Table 14 gives the time required to root the majority of crops tested and the time of year in which the tests were conducted. The cuttings were removed from the media when the majority of roots were one-half inch long, which is considered the proper stage, Figure 6. The number of days given represents the average of three replications and at least 100 cuttings in each.

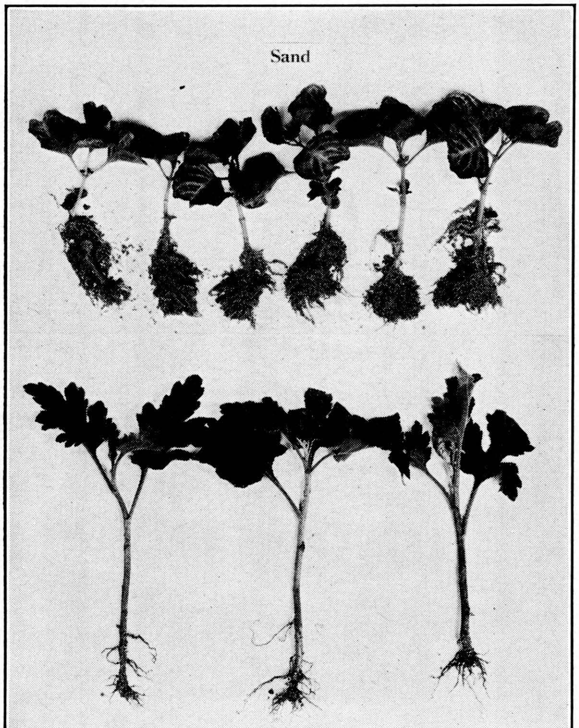

Fig. 6.—Well rooted cuttings ready to be potted

TABLE 14.—Time Required for Rooting

Crop	Season	Days required for rooting
Coleus	Fall, 1927	18
Coleus	Winter, 1927	23
Coleus	Fall, 1928	20
Achyranthes	Fall, 1927	24
Carnations	Spring, 1928	26
Carnations	Late spring, 1928	22
Carnations	Spring, 1929	24
Geraniums	Fall, 1928	42
Geraniums	Spring, 1929	44
Fuchsias	Winter, 1928	38
Chrysanthemums	Spring, 1929	22
Begonia (Gracilis)	Spring, 1929	21
Vinca (vine)	Spring, 1929	28
Ivy (English)	Spring, 1928	26

The figures show that the cuttings rooted in from 18 to 42 days after they were placed in the media. Several environmental factors affect the time of rooting. Roots form quicker in higher temperatures, provided they are not too high as has already been shown. Allowing the cuttings to wilt retards the rooting. Roots form quicker during the longer days, provided other environmental factors are satisfactory. Propagators should be able to root the majority of greenhouse crops in from 3 to 6 weeks. The slight gain in time secured by raising the temperature would probably not make up for the extra losses from damping-off caused by the high temperatures.

Cuttings left in the cutting bench too long become spindling, yellow in color, and are more subject to losses than those taken out when the roots are properly developed. The smaller root systems are also easier to pot. Nothing is gained with most crops by leaving cuttings in the bench after the roots are one-half inch long. Crops propagated from leaf cuttings are exceptions to this rule and are often left in the medium where rooted until a shoot develops.

EFFECT OF MEDIA ON GROWTH AFTER POTTING

Practically all of the cuttings used in the tests of media grew when they were potted. The question is often raised, however, as to the effect of the medium on the growth of the cutting after potting.

Seventy-five cuttings each of Verschaffelti and Firebrand coleus and Red Wing geraniums were taken from each of several media. They were potted into 2½-inch pots containing the same kind of soil and treated alike as to water, shade, and general cultural practices after they were removed from the medium. All cuttings of each variety were cut at an equal length before they were placed in the cutting bench.

Table 15 gives the height of the plants on December 20, 1927. They were potted on November 7.

TABLE 15.—Growth of Cuttings from Different Media After Potting

Media	Height			
	Firebrand Coleus	Verschaffelti Coleus	Red Wing Geranium	Average
	Inches	*Inches*	*Inches*	*Inches*
½ sand—½ peat moss	6.5	5.0	6.0	5.8
½ sand—½ slag	6.25	3.5	5.25	5.0
Slag	6.0	3.25	4.75	4.6
Sand	5.75	3.5	5.75	5.0
½ slag—½ peat moss	5.75	3.0	5.0	4.5
½ sand—½ Sphagnum moss	5.5	3.25	5.25	4.6
½ slag—½ Sphagnum moss	5.25	3.25	4.75	4.4

The cuttings rooted in ½ sand and ½ peat moss gave the best growth after the cuttings were potted, Table 15. They were followed by sand, and by ½ sand and ½ slag which gave the average growth. Although the growth after potting is important, the increased early growth secured from some of the media after potting is not very important. All of the cuttings in this test grew. This fact is more significant than any increased growth secured.

Some of the media adhered to the roots much better than others. Cuttings that were not potted immediately after taking from the cutting bench would perhaps respond better to the media that adhere to the roots.

The roots produced in sand and in slag or combinations, in particular, were much whiter in color and cleaner in appearance than those produced in the mosses. Although the roots produced in the mosses were perfectly healthy, the cleaner appearing roots might be more desirable when the propagator was shipping the rooted cuttings.

ACIDITY OF THE CUTTING MEDIA

Zimmerman and Hitchcock (17), Chadwick (5), and others have reported on the relationship of the acidity of the medium and the resulting rooting of the cuttings in it. They have shown that members of the Heath family (which includes such plants as rhododendrons, blueberries, azaleas, and others) are greatly benefited by placing a good proportion of peat moss in the rooting medium. It is well known that this family of plants requires an acid soil in which to grow; at least calcium is very detrimental to them. There seems to be no question about the acidity of the rooting medium also being of importance to this family of plants.

Other authors have recently secured a better percentage of rooting with other kinds of plants when peat moss was mixed with sand as a rooting medium.

The hydrogen-ion concentration of the different media used at Wooster was determined, an example being given in Table 16. The media were mixed, watered with tap-water, and the reactions tested at various intervals. The readings varied constantly, all media tending to become more alkaline. The reading when the roots were first appearing is given in this case.

TABLE 16.—Reaction of Rooting Media

Media	pH value	Degree of acidity or alkalinity
Sand	8.05	Alkaline
Peat moss (German)	4.85	Very acid
Slag	8.05	Alkaline
⅔ slag—⅓ Sphagnum moss	8.35	Alkaline
⅔ sand—⅓ peat moss	8.25	Alkaline
⅔ sand—⅓ Sphagnum moss	8.45	Alkaline
⅔ slag—⅓ peat moss	8.10	Alkaline
½ sand—½ peat moss	8.20	Alkaline
½ slag—½ peat moss	7.85	Slightly alkaline
½ sand—½ slag	8.20	Alkaline

The peat moss, before it was placed in the cutting bench, tested pH 3.85, which is very acid. When it was watered with tap water for approximately 2 weeks the acidity was changed to pH 4.85. Peat moss and sand mixed in equal volumes, or at the rate of two parts of sand to one of peat moss by volume, were alkaline with a pH of 8.20 and 8.25, respectively. The peat moss, therefore, though very acid, did not permanently lower the alkalinity of the sand when mixed with it under these conditions. The heavy watering when the cuttings were first placed in the medium and subsequent waterings apparently leached the active acidity from the medium, or it is highly buffered.

Tests with soil modifiers are being conducted at Wooster. Peat moss has been mixed with compost in some of these tests. The peat moss, though itself very acid, does not permanently make the soil in which it is mixed very much more acid. This might be explained by the fact that the peat moss is very absorptive of soil moisture and by the buffer action of the peat moss.

There is not any apparent correlation between the degree of acidity and the percentage of rooting at the time roots first appear. Any increases secured from the use of peat moss, under the conditions of this experiment, are apparently due to moisture relations rather than to differences in acid reactions. As previously indicated, conditions suitable for active growth of the plant in general also seem to be those most suitable for rooting of the cuttings. Wiggin and Gourley (15) report that the majority of greenhouse flower crops show a wide range of soil reaction at which plants make a satisfactory growth, provided extremes of acidity or alkalinity are not encountered. This apparently holds true in the case of cuttings where the reaction has been recorded. Plants requiring a definite soil reaction for growth no doubt benefit by an approximate reaction in the rooting medium as cited. Those having a wide tolerance range for growth in soils will apparently tolerate a range of reaction in the cutting medium if extremes are avoided.

USE OF CHEMICALS IN ROOTING CUTTINGS

The use of chemicals has been advocated for stimulating rooting. Potassium permanganate was found to be beneficial by Curtis (7). Chadwick (4) also reports on different chemicals as aids to propagation of deciduous shrubs and evergreen cuttings. The formation of roots has been linked with the carbohydrate supply in the cutting by Reid (13). This has led to the use of sugar solutions of various strengths, in which the cuttings are soaked before being placed in the cutting bench. Tests were run at Wooster with sugar solutions and potassium permanganate during the winter of 1929 and the spring of 1930.

One and 2 per cent sugar solutions were used. The cuttings were soaked in these solutions for 12 hours, then washed thoroughly in water before placing in the sand. Chadwick (3) found that fungous troubles were liable to occur when cuttings were soaked in sugar solutions unless the cuttings were well washed with water after treatment.

The potassium permanganate was used at a one-hundredth molecular solution, or about one ounce to 5 gallons of water. One lot of cuttings was likewise soaked for 12 hours in the potassium permanganate solution and then placed directly in the sand. Another lot of cuttings was watered with a very dilute solution of the potassium permanganate instead of water wherever moisture was necessary. The permanganate in this treatment was mixed with water until the color was slightly pink. No attempt was made to determine the exact strength of the solution, which was very dilute. The figures given are for lots of 100 cuttings at three different times, or for 300 cuttings of each kind of plant.

TABLE 17.—Effect of Chemicals on Rooting Cuttings

Crop	1% sugar solution	2% sugar solution	$KMnO_4$	Watered with $KMnO_4$	Sand untreated
	Per cent rooted	Per cent rooted	Per cent rooted	Per cent rooted	Per cent rooted
Geranium	70	55	33	45	73
Fuchsia	100	80	100	100	100
Begonia	64	44	68	100	100
Carnation	86	96	16	87	89
Ivy	85	100	100	100	100
Average	81	75	63	86	92

The untreated sand resulted in the best average percentage of rooting, Table 17. Watering the sand with the dilute solutions of potassium permanganate also resulted in a good percentage. The one-hundredth molecular solution of potassium permanganate in which cuttings were placed for 12 hours blackened the cut area of many of the cuttings and did not seem at all desirable at this strength. Both 1 per cent and 2 per cent sugar solutions were too strong for very succulent cuttings, such as the Begonias. Practically no roots formed on the soaked portion of the cuttings, but roots formed above the soaked area. Otherwise, the figures would have been much lower. The short cuttings caused by the rotting of the lower part of the cuttings treated were very difficult to pot and handle.

As a result of this test, it would seem evident that the use of sugar or potassium permanganate in which cuttings of these crops are to be soaked prior to placing in the cutting medium is not advisable when used at the strengths used in these tests. Although dilute solutions of potassium permanganate used for watering the cuttings did not increase the rooting over no treatment, a good percentage was secured with this treatment. Propagators might find this solution a means of checking damping-off should this trouble appear in a lot of cuttings.

Gregory and Davis (8) recommend using potassium permanganate (1 oz. to 4 gallons of water) watered on the medium before the cuttings are placed in it. Their recommendation was tried with no detrimental effects. Watering the medium with the permanganate solution would be particularly desirable in case the media were to be used for more than one lot of cuttings.

Semesan gave very poor results and could not be recommended, Table 1.

The use of chemicals for rooting cuttings in general is not recommended with succulent greenhouse crops, though it may be beneficial to some. It requires extra time and risk, which are not warranted with the crops tested.

VARIETAL DIFFERENCES IN REGARD TO ROOTING

Popular literature on flower growing often states that cuttings of certain varieties of plants are high in price due to the difficulty encountered in rooting the cuttings. When cuttings of different varieties are removed from the cutting bench certain varieties are noted to root much better than others that have been treated in the same manner.

Several varieties of chrysanthemums and carnations have been tested at Wooster to determine possible varietal differences in ease of rooting. Some differences encountered with chrysanthemums have already been reported from this Station (Bull. 439). Further tests gave similar results during the spring of 1930, the tests including many more varieties. The variety Blanche again produced the poorest per cent of roots, 78.7 per cent. Many varieties rooted 100 per cent. Soft, vigorous, luxuriant, easy-breaking varieties, in general, rooted best, as indicated in Bulletin 439.

Cuttings of a number of varieties of carnations were placed in the sand December 4 and taken out December 28. The majority were well rooted when removed from the sand. Practically all those that did not root damped-off. The results secured are shown in Table 18.

TABLE 18.—The Rooting of Carnation Varieties

Variety	Put in	Taken out	Rooted
	Number	*Number*	*Per cent*
Maine Sunshine	25	18	72.0
North Star	25	14	56.0
White Ward	30	28	93.3
Harvester	30	29	96.7
White Eldora	30	22	73.3
Laddie	25	15	60.0
Betty Lou	30	30	100.0
Jewel	30	30	100.0
Spectrum	30	28	93.3
Pink Delight	30	18	60.0
Early Dawn	30	29	96.7
Eldora	30	16	53.3
Hilda	30	30	100.0
Super Supreme	30	26	86.7
Boston Ward	30	27	90.0
Pink Eldora	30	21	70.0
Winsome	30	22	73.3
Morning Glow	30	18	60.0
Beacon	30	20	67.7
Sophelia	30	29	96.7
Red Matchless	30	27	90.0
Enchantress Supreme	30	29	96.7
Mrs. C. W. Ward	30	29	96.7
Akehurst	30	25	83.3
White Matchless	30	28	93.3

Considerable variation occurred between the several varieties tested. Although this test was for only the one season, with a small number of cuttings of each variety, the results are in accord with observations. The Maine Sunshine, North Star, Laddie, and Morning Glow varieties of carnations rooted poorly as compared with Betty Lou, Hilda, and Mrs. C. W. Ward. No relationship could be observed between succulence, general vigor, yield, and rooting with carnations. Considerable variation in rooting will be encountered with different lots of cuttings under the same conditions of treatment.

PROPAGATION BY SEEDS

Seeds are the normal propagative bodies of the flowering plants. Seeds are usually made up of an embryo with its protective parts and usually a supply of stored food. This food is used by the young plant until it is capable of making its own food.

When a seed is placed in the proper conditions growth generally starts, and this is commonly called germination. Germination is complete when the seedling is able to support itself. Some seeds require a rest or dormant period before germination is possible.

Seeds are able to complete their germination provided the proper amount of moisture, heat, and oxygen are provided.

Oxygen is usually present in the soil in sufficient quantities for germination; so it is disregarded. Soil that is not too compact nor too wet will contain sufficient oxygen for germination.

The temperature at which seeds should be held for proper germination is of importance. Temperatures that are too high or too low may cause seeds to rot before germination is completed. Seeds from plants that grow best at cool temperatures apparently germinate better at cool temperatures and vice versa. Seeds held at temperatures agreeable to the plant from which they came will germinate satisfactorily. Slight increases in temperature will hasten germination without injury to the seedlings.

Moisture is commonly the limiting factor in the proper germination of seeds. Too much moisture will decrease the percentage of germination, and more damping-off is likely to occur.

The medium in which the seed is sown regulates moisture to a great extent. The medium should hold moisture in sufficient quantities for germination, without too frequent applications of water. Sand has to be watered relatively often to keep it at the proper moisture content. Peat moss, on the other hand, will hold water for a long period of time. Ordinary soil or compost holds moisture in proportion to the humus it contains and the texture of the soil.

The medium should be friable and should not bake or crust on the surface. This allows the shoots to break through the surface easily. Soils containing a high percentage of silt or clay readily form a hard crust upon drying. Sand does not form that crust if washed so that it does not contain silt or clay.

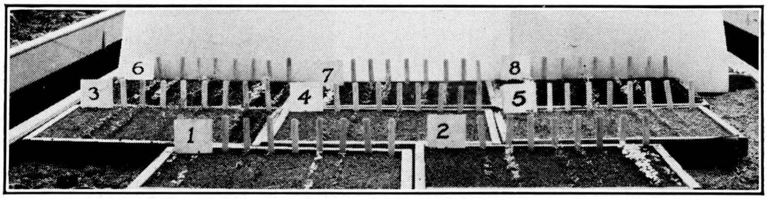

Fig. 7.—Propagation of seeds in different soil mixtures. 1. Compost. 2. Peat moss. 3. ½ Compost—½ Peat moss. 4. Sand. 5. ½ Sand—½ Compost. 6. ½ Sand—½ Peat moss. 7. ½ Sand—½ Muck. 8. Muck

It is essential in some cases that the medium contain some plant food. Large seeds can be germinated satisfactorily in pure sand as they readily reach sufficient size to transplant. Other seeds, such as snapdragon and petunia, will start growth in the sand but will not ordinarily reach sufficient size to handle readily. A medium containing a small amount of plant food in a slowly available form is beneficial when sowing the small-seeded plants.

TABLE 19.—Germination of Different Annuals in Various Soil Combinations, 1928

Crop	Compost	½ compost ½ sand	Peat	Muck	Sand	½ compost ½ peat	½ muck ½ sand	½ sand ½ peat
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Ageratum	24	50	65	57	64	26	23	64
Verbena, yellow	33	53	44	51	46	59	50	49
Verbena, blue	8	28	36	27	45	43	32	38
Aster, Crego Gi. pink	44	37	70	50	71	47	56	70
Aster, Cal. Gi. Lt. blue	29	40	63	32	62	34	38	54
Aster, Cal. Gi. D. rose	38	55	72	66	71	38	58	68
Aster, Sunshine	48	53	39	50	57	41	41	51
Aster, single	42	38	63	65	57	40	51	57
Average	33.25	44.25	56.50	49.75	59.12	42.00	43.62	56.37

Several different media and combinations were tried in tests at Wooster for their effect on germination, Figure 7. Samples of 100 seeds each were tested for germination in a seed germinator under ideal conditions. Other lots of 100 seeds were placed in the different media. Three lots of each variety were planted at different dates. The figures given in Table 19 are the averages for the three planting dates.

A similar test was conducted the following spring on a few garden annuals, Table 20. The results were the same for the three leading media as for the previous year. Sand was first, peat moss second, and one-half sand and one-half peat moss was third in both trials.

TABLE 20.—Per Cent Germinated of Different Annuals in Various Soil Combinations, 1929

Crop	Artificial germination	Compost	½ peat ½ sand	½ muck ½ sand	½ sand ½ compost	Sand	Muck	½ compost ½ peat	Peat
Petunia	30	19	11	26	25	22	45	21	42
Nicotiana	12	2	15	4	8	20	7	14	29
Scabiosa	46	24	34	32	18	43	22	13	29
Stocks	70	60	77	81	53	81	57	38	50
Cosmos	63	29	57	44	41	57	51	28	51
Marigold	32	23	36	26	14	35	17	21	17
Verbena	25	15	11	22	13	19	18	21	17
Balsam	87	36	76	73	16	62	80	74	80
Aster (Calif. Gi.)	23	13	29	34	18	24	16	22	27
Average	43.11	24.55	38.44	38.00	22.89	40.33	33.67	28.00	38.89

As has already been indicated, sand on very small seeds does not give a sufficient growth for ease in handling the seedlings. Further work with peat moss has shown that damping-off is liable to be encountered unless great care is taken to provide the proper quantity of moisture.

A combination of sand and peat moss should prove satisfactory under the average conditions. It does not form a crust, holds moisture, and the seedlings make a good, rapid growth in it.

It is interesting to note that compost alone gave the poorest results in 1928, and next to the poorest in 1929 (Table 19). The soil from which the compost was made was a silt loam. The poor showing the compost made was due to the crust formed on the surface when it dried out after watering.

Counts were kept of the plants damped-off in the different media. Sand gave the least damping-off, with peat moss, muck, and compost giving increasing amounts in the order given. Damping-off depends to a large degree on moisture applications. The different media differ somewhat in regard to its prevalence, however, as indicated.

SUMMARY

The following conclusions deal with the results secured with succulent greenhouse and garden flower and foliage crops.

Propagation by cuttings:

1. The material for the cutting should not be too hard or too succulent. New growth that is not elongating too rapidly usually meets these requirements.

2. The location of the cut, whether between the nodes or at them, did not materially affect the percentage of rooting. Cuts made at random proved satisfactory with the majority of crops tested.

3. Crops having conspicuous nodes and long internodes, such as Vinca and Ivy, produce the greatest number of roots directly below the node regardless of where the cut was made. Cuttings of this type may be potted more easily if the cut is made within one inch of the node and below it.

4. The majority of greenhouse plants root directly above the cut surface, regardless of where the cut is made.

5. The yield of carnations was not affected by the location on the mother plant from which the cutting was taken. A good strong healthy cutting is about the only requirement.

6. Promiscuous trimming of cuttings is not advisable. Larger root growth and greater top growth immediately following the propagation result when less trimming is done. Trimming off foliage affects the moisture of the medium, the humidity, the "balance" in the plant and involves many physiological changes difficult to interpret.

7. High air temperatures are detrimental for rooting cuttings.

8. Humidity, shading, temperatures, and water have to be properly controlled by the location of the cutting bench and other artificial means for successful rooting of cuttings. These conditions differ with different crops.

9. Cuttings root satisfactorily in a wide range of media if they are properly handled as to water and shade. The medium apparently serves more as a control of soil moisture than any other service or effect it may have on the cuttings in it.

10. Sand, due to its abundance and relatively low cost, is a satisfactory medium for most cuttings.

11. The time required for roots to form depends on the season of the year, the crop, and the environmental factors.

12. The medium in which the cutting was rooted affected its growth after potting but not in a sufficient amount to warrant the use of any one medium for its effect on after-growth.

13. Cuttings rooted in very acid and very alkaline media satisfactorily.

14. The use of chemicals in which the cuttings are placed prior to placing in the medium in the propagation of many succulent greenhouse crops is not to be recommended with our present available knowledge. Potassium permanganate watered on the media in dilute strengths served as a good preventative of fungous troubles.

15. Different varieties of the same species of plants differ in the ease of their propagation.

Propagation by seeds:

1. Seeds germinate satisfactorily if held at the temperature at which the crop makes satisfactory growth.

2. Moisture is commonly the limiting factor in the proper germination of seeds. Too much moisture causes rots and damping-off of the seedlings that have started.

3. A satisfactory medium for seed sowing should hold sufficient moisture for proper germination, should not crust over easily on drying, and need contain very little mineral salts if the seedlings are to be transplanted.

4. A mixture of one-half sand and one-half moist, imported, granulated peat moss makes a satisfactory soil medium for starting seeds. Several materials have been found satisfactory, however, if given the proper environmental conditions.

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